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RESEARCH MEMORANDUM

TRANSONIC WIND-TUNNEL INVESTIGATION OF THE EFFECT OF A HORIZONTAL TAIL ON LONGITUDINAL STABILITY OF TWO 60° SWEPTBACK-WING—BODY CONFIGURATIONS WITH ASPECT RATIOS OF 2.67 AND 4.00

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

February 20, 1958

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TRANSONIC WIND-TUNNEL INVESTIGATION OF THE EFFECT OF A HORIZONTAL TAIL ON LONGITUDINAL STABILITY OF TWO 60° SWEPTBACK-WING—BODY CONFIGURATIONS WITH ASPECT RATIOS OF 2.67 AND 4.00

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SUMMARY

An investigation of the effect of a 60° sweptback horizontal tail at two vertical locations on the static longitudinal stability of two 60° sweptback-wing—body configurations with aspect ratios of 2.67 and 4.00 has been conducted in the Langley 8-foot transonic pressure tunnel. Tests were made at Mach numbers from 0.80 to 1.18 for angles of attack from -3° to about 15°.

The addition of the horizontal tail to the wing-body configurations at either of the two locations reduced the pitch-up tendency but did not eliminate it. The tail was slightly more effective at subsonic speeds immediately after the pitch-up tendency when located below the extended wing chord plane. At low lift coefficients, stability changes with increasing Mach number corresponding to a rearward movement of the neutral point of approximately 12 percent and 19 percent of the mean aerodynamic chord occurred for the aspect-ratio-2.67 and aspect-ratio-4.00 configurations, respectively.

INTRODUCTION

In an investigation reported in references 1 and 2, a 60° sweptback-wing—indented-body configuration was found to have exceptionally high lift-drag ratios at transonic speeds; however, the longitudinal stability characteristics were unsatisfactory at moderate lift coefficients. Various devices were added to the wing (ref. 2) to improve the stability characteristics but none were adequate.

The purpose of the present investigation is to determine the effect of a 60° sweptback horizontal tail on the longitudinal stability characteristics of two other 60° sweptback-wing—body configurations that have also been designed to have high lift-drag ratios at transonic speeds. The aspect ratios of the two wings are 2.67 and 4.00. Each wing-body configuration was tested alone and with the horizontal tail at 0° angle of incidence in two vertical positions - below the wing chord plane and slightly above the wing chord plane. Data were obtained over a Mach number range from 0.80 to 1.18 through an angle-of-attack range from -3° to about 15°.

SYMBOLS

a	airfoil-section mean-line designation, fraction of chord from leading edge over which design load is uniform
$\bar{c}$	mean aerodynamic chord
C_L	lift coefficient, Lift/qS_w
C_D	drag coefficient, Drag/qS_w
C_m	pitching-moment coefficient about $0.25\bar{c}_w$, Pitching moment$/qS_w\bar{c}_w$
$\frac{dC_m}{dC_L}$	slope of pitching-moment curve
l	tail length, distance from $0.25\bar{c}_w$ to $0.25\bar{c}_t$ measured parallel to wing chord plane
M	free-stream Mach number
q	free-stream dynamic pressure
S	total area
V_t	tail volume coefficient, $\frac{l}{\bar{c}_w}\frac{S_t}{S_w}$
α	angle of attack of model measured from fuselage center line, deg

Subscripts:

w wing

t tail

APPARATUS AND TESTS

Tunnel

The test section of the Langley 8-foot transonic pressure tunnel is approximately square in cross section. The upper and lower walls of the test section are slotted to allow continuous operation through the transonic speed range without choking.

The tests were conducted at approximately atmospheric stagnation pressure and the stagnation temperature in the tunnel was automatically controlled and held constant at 123° F. The tunnel air was dried sufficiently to lower the dewpoint below 0° F in order to prevent the formation of condensation shocks.

Models

The plan forms and dimensions of the wing-body-tail configurations are shown in figure 1. Both the wings and the tail were constructed of steel. The model was sting supported as shown in figure 2. The body coordinates are given in table I and the geometric characteristics of the wings and tail are given in table II.

The wings tested have the 0.25-chord line swept back 60°, have a taper ratio of 0.15, and are mounted $\frac{1}{2}$ inch above the body center line at 0° angle of incidence. The wing of aspect ratio 2.67, shown in figure 1(a), has a streamwise NACA 64A206, a = 0 airfoil section at the root and tapers linearly to a streamwise NACA 64A203, a = 0.8 (modified) airfoil section at the 50-percent semispan. The same airfoil section is used from the 50-percent-semispan station to the wing tip. The airfoil coordinates for a given percent semispan are the same as those given in reference 3. The wing of aspect ratio 4.00, shown in figure 1(b), is 1.5 times as thick as the wing of aspect ratio 2.67 in order to have approximately the same structural characteristics.

The horizontal tail used in this investigation has the 0.25-chord line swept back 60°, a taper ratio of 0.15, and an aspect ratio of 2.67.

The tail has a streamwise NACA 64A005 airfoil section at the root and tapers linearly to an NACA 64A002 airfoil section at the tip. The tail could be mounted in two positions as shown in figure 1.

Tests

The wing-body configurations were tested with the tail off and with the tail on in the low position and in the high position over the Mach number range from 0.80 to 1.18, except that the configuration having the aspect-ratio-4.00 wing and the tail in the low position was not tested below a Mach number of 0.90. The normal, axial, and pitching-moment loads of the complete configuration were measured with an internal strain-gage balance. Data were not recorded in the Mach number range from 1.03 to 1.18 since, in this range, the data may have been affected by reflections of the fuselage bow wave from the tunnel walls. The variation of Reynolds number, based on $\bar{c}_w$, with Mach number is shown in figure 3.

The angle of attack was measured by a strain-gage attitude transmitter mounted in the body ahead of the wing. The angle-of-attack range was limited by the maximum allowable load on the balance and varied from -3° to about 18° at the subsonic Mach numbers and from -3° to 12° or 15° at the supersonic Mach numbers.

CORRECTIONS AND ACCURACY

The drag data for these tests have been adjusted to the condition of free-stream static pressure at the base of the body. Except for the base-pressure adjustments, sting interference effects have been neglected. No corrections to the data for the aeroelastic properties of the models have been made. Since the blockage area of the model configurations was small, corrections to the test data for boundary interference are not believed necessary in the slotted test section. (See ref. 4.)

The accuracy of the measured coefficients is estimated to be as follows:

C_L . . . . ±0.007
C_D . . . . ±0.001
C_m . . . . ±0.002

The local deviations in Mach number in the region of the model were no larger than 0.003 at the subsonic Mach numbers and did not exceed

0.010 as the Mach number was increased to 1.18. The model angle of attack is estimated to be correct within ±0.1°.

RESULTS AND DISCUSSION

The basic aerodynamic characteristics are shown in figure 4 for the aspect-ratio-2.67 and in figure 5 for the aspect-ratio-4.00 wing-body configurations with and without the horizontal tail. It should be noted that, in order to facilitate presentation of the data, staggered scales have been used in many of the figures and care should be taken in identifying the zero axis for each curve.

Longitudinal Stability Characteristics With Tail Off

The variation of pitching-moment coefficient with lift coefficient (figs. 4(c) and 5(c)) indicates a large unstable break or pitch-up characteristic in the pitching-moment curves at the subsonic Mach numbers for both wing-body configurations at a lift coefficient of approximately 0.45 followed by a large stable break at a lift coefficient of approximately 0.70. The unstable break in the pitching-moment curves occurs at approximately the same lift coefficient that the slope of the lift curves (figs. 4(a) and 5(a)) begins to decrease. At supersonic speeds, the unstable break in the pitching-moment curves becomes less severe with increasing Mach number starting at Mach number 1.00 for the aspect-ratio-2.67 wing and above Mach number 1.03 for the aspect-ratio-4.00 wing.

The unstable pitching-moment changes at subsonic and supersonic speeds are the result of lift losses over the outboard wing sections, which are probably caused by boundary-layer separation on the wing upper surface. Reasons for separation are believed similar to those indicated for a 45° swept-wing model in reference 5. At the lower Mach numbers separation is attributed to the effects of a leading-edge separation vortex, and at the higher Mach numbers shocks that extend laterally across the wing cause separation of the thickened boundary layer over the outboard wing sections. With increase in Mach number these shocks move rearward on the wing; this movement of the shock reduces the separated flow area and results in an improvement in the pitching-moment characteristics at supersonic speeds.

Longitudinal Stability Characteristics With Tail On

The changes in the longitudinal stability characteristics of the wing-body configurations due to the addition of the tail are perhaps best indicated by the variation of $\frac{dC_m}{dC_L}$ with lift coefficient as shown in figure 6. In these curves the destabilizing or pitch-up tendency appears as an abrupt decrease in the negative value of $\frac{dC_m}{dC_L}$ at moderate lift coefficients. Adding the tail in either position tended to reduce the abrupt change in the slopes and also the maximum change in many cases, but it did not eliminate the destabilizing tendency. At supersonic speeds, adding the tail generally delayed the destabilizing tendency to higher lift coefficients. Lowering the tail had the greatest effect at subsonic speeds where it increased stability over a small lift range after pitch-up.

The variation of $\frac{dC_m}{dC_L}$ with Mach number at a value of C_L of 0.2, shown in figure 7, indicates a rearward movement of the neutral point $\left(\text{assuming } \frac{dC_m}{dC_L} \text{ is indicative of neutral point at low lift coefficients in this case}\right)$ with increasing Mach number of approximately 12 percent $\bar{c}_W$ and 19 percent $\bar{c}_W$ for the aspect-ratio-2.67 and aspect-ratio-4.00 wing-body configurations, respectively. The contribution of the tail increases slightly with increasing Mach number as indicated in figure 7.

The tail volume coefficient of these configurations is comparatively low, 0.247 when the aspect-ratio-4.00 wing is used and 0.202 when the aspect-ratio-2.67 wing is used. It appears that the pitch-up tendency might be further reduced by increasing the tail length and area, by decreasing the sweepback of the tail, and by adding auxiliary devices to the wings.

CONCLUSIONS

An investigation of the effect of a 60° sweptback horizontal tail at two vertical locations on the static longitudinal stability of two 60° sweptback-wing—body configurations at angles of attack from -3° to about 15° leads to the following conclusions:

1. Adding the tail to the wing-body configurations at either of the two locations reduced the magnitude of the pitch-up tendency but did not eliminate it.

2. Lowering the tail to the position below the extended wing chord plane resulted in a slight increase in effectiveness immediately after pitch-up at subsonic speeds.

3. At low lift coefficients, stability changes with increasing Mach number corresponding to a rearward movement of the neutral point of approximately 12 percent and 19 percent of the mean aerodynamic chord occurred for the aspect-ratio-2.67 and aspect-ratio-4.00 configurations, respectively.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., November 18, 1957.

REFERENCES

1. Whitcomb, Richard T., and Fischetti, Thomas L.: Development of a Supersonic Area Rule and an Application to the Design of a Wing-Body Combination Having High Lift-to-Drag Ratios. NACA RM L53H31a, 1953.

2. Fischetti, Thomas L.: Effects of Fences, Leading-Edge Chord-Extensions, Boundary-Layer Ramps, and Trailing-Edge Flaps on the Longitudinal Stability of a Twisted and Cambered 60° Sweptback-Wing—Indented-Body Configuration at Transonic Speeds. NACA RM L54D09a, 1954.

3. Loving, Donald L.: A Transonic Investigation of Changing Indentation Design Mach Number on the Aerodynamic Characteristics of a 45° Sweptback-Wing—Body Combination Designed for High Performance. NACA RM L55J07, 1956.

4. Whitcomb, Charles F., and Osborne, Robert S.: An Experimental Investigation of Boundary Interference on Force and Moment Characteristics of Lifting Models in the Langley 16- and 8-Foot Transonic Tunnels. NACA RM L52L29, 1953.

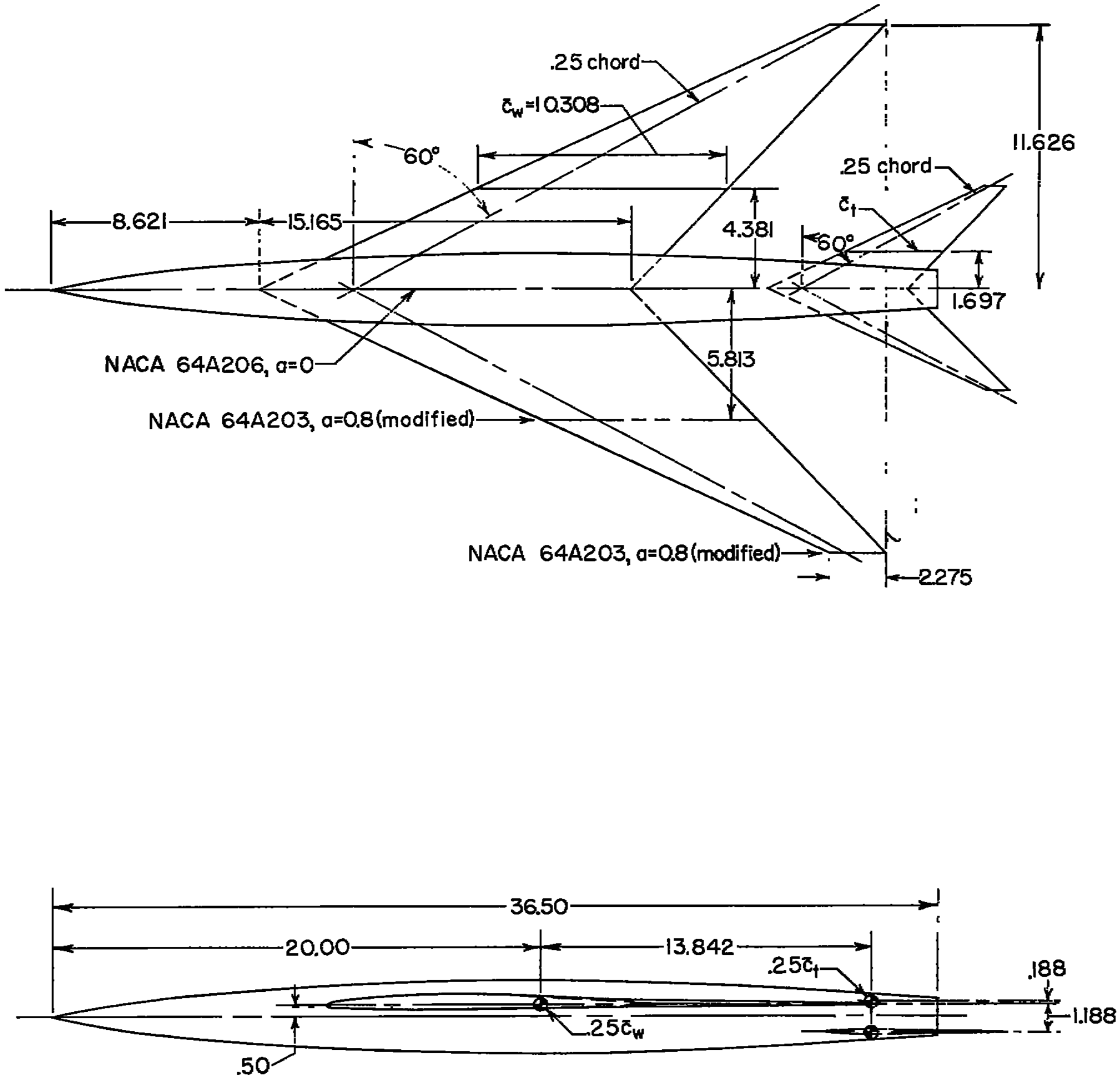
5. West, F. E., Jr., and Henderson, James H.: Relationship of Flow Over a 45° Sweptback Wing With and Without Leading-Edge Chord-Extensions to Longitudinal Stability Characteristics at Mach Numbers From 0.60 to 1.03. NACA RM L53H18b, 1953.

TABLE I.- BODY COORDINATES

Station, in. from nose	Body radius, in.
0	0
.5	.165
1.0	.282
2.0	.460
3.0	.612
4.0	.743
6.0	.969
8.0	1.150
10.0	1.290
12.0	1.404
14.0	1.493
16.0	1.552
18.0	1.590
20.0	1.606
21.5	1.600
23.5	1.570
25.0	1.532
27.0	1.460
29.0	1.360
31.0	1.231
31.7	1.181
34.0	1.019
36.0	.879
36.5	.844

TABLE II.- GEOMETRIC CHARACTERISTICS OF MODELS

	Wings		Tail
Aspect ratio	4.0	2.67	2.67
Taper ratio	0.15	0.15	0.15
Total area, sq in.	202.75	202.75	30.41
Dihedral, deg	0	0	0
Geometric twist, deg	0	0	0
Span, in.	28.478	23.252	9.006
Sweepback:			
0.25-chord line, deg	60.00	60.00	60.00
Leading edge, deg	62.45	63.54	63.54
$\bar{c}$, in.	8.416	10.308	3.992
S_t/S_w	0.15	0.15	-----
$l/\bar{c}_w$	1.645	1.343	-----
V_t	0.247	0.202	-----



(a) Wing aspect ratio, 2.67.

Figure 1.- Details of the configurations tested. All dimensions are in inches.

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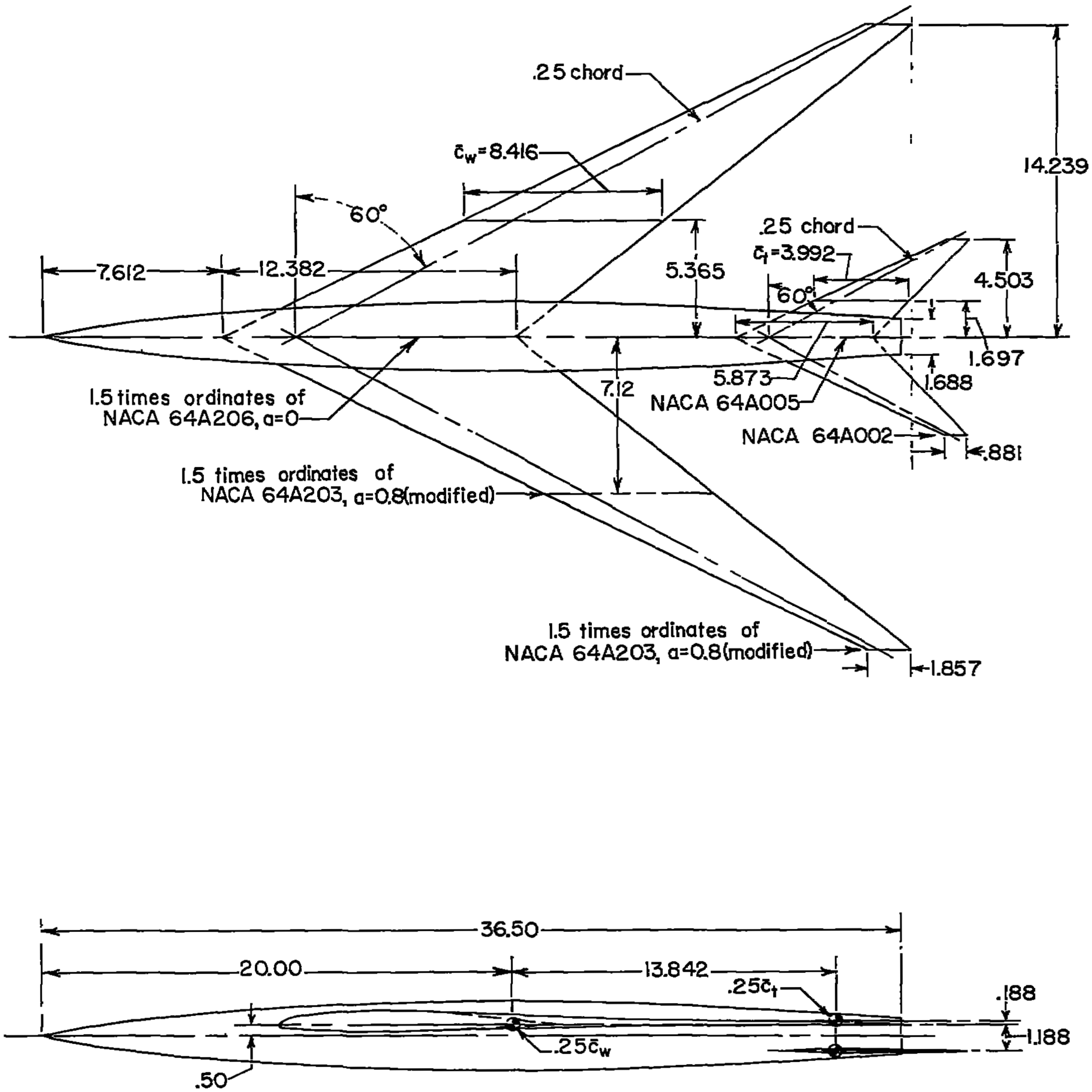

(b) Wing aspect ratio, 4.00.

Figure 1.- Concluded.

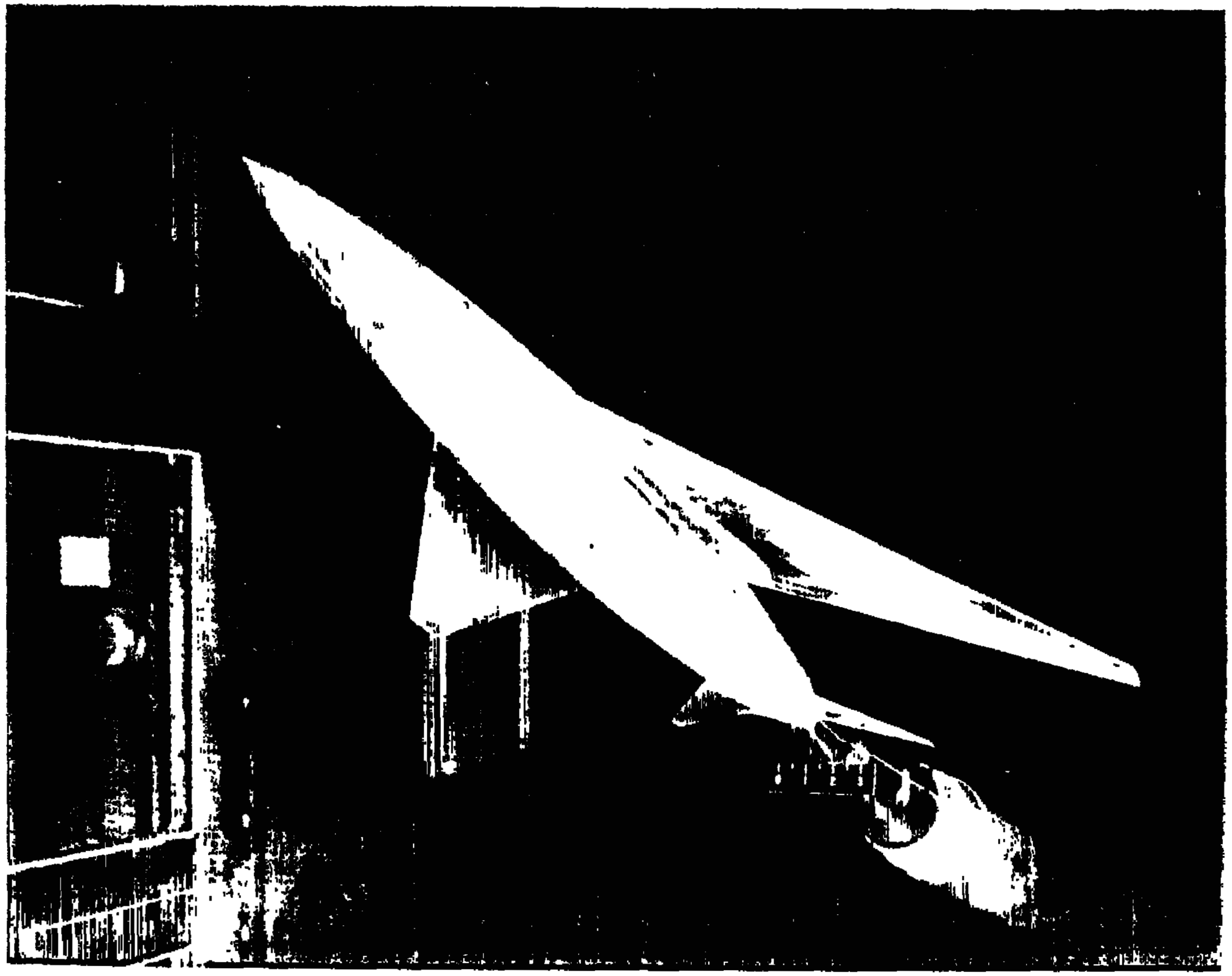

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Figure 2.- Model in the Langley 8-foot transonic pressure tunnel with the aspect-ratio-2.67 wing and the tail in the low position.

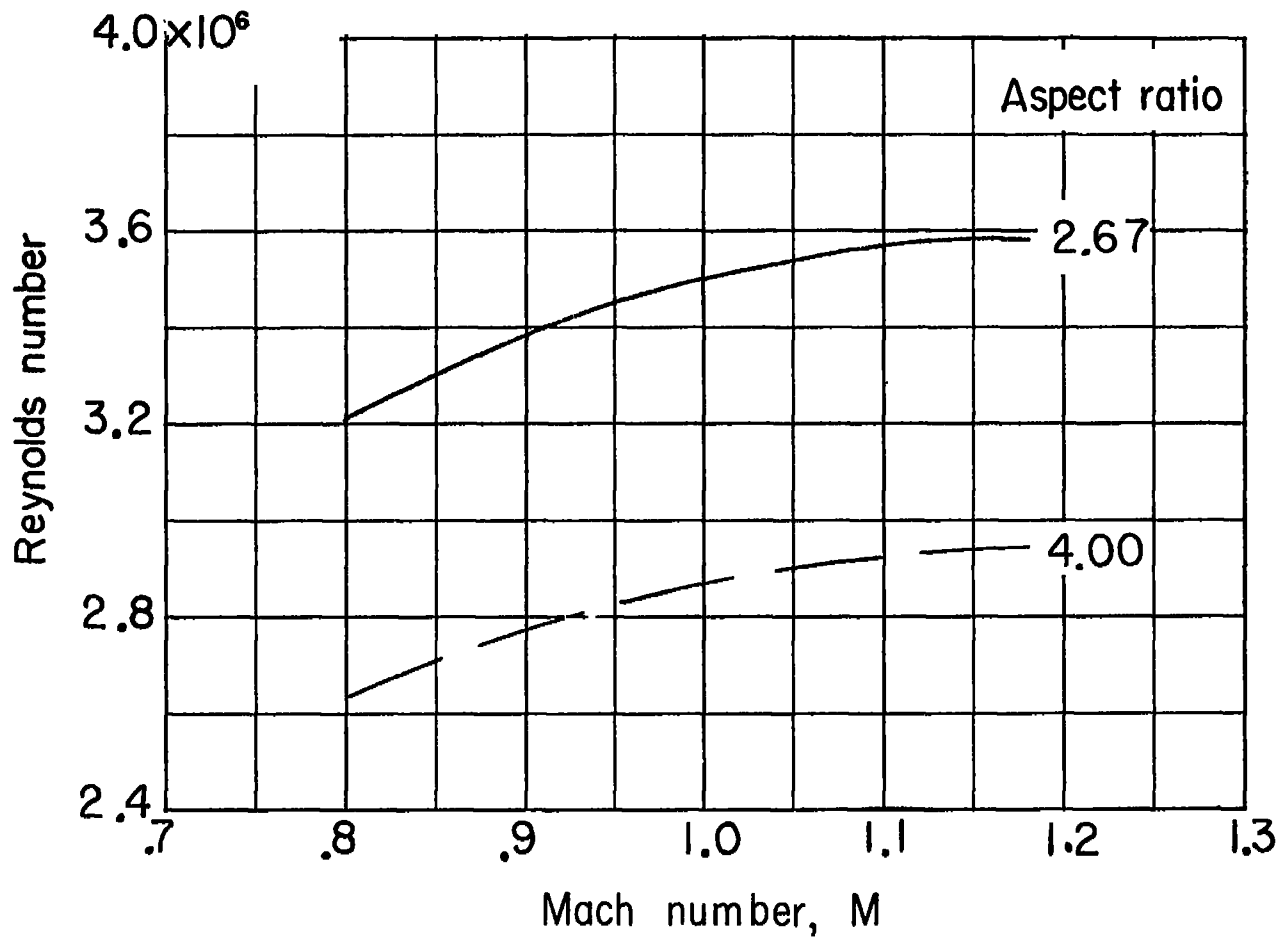
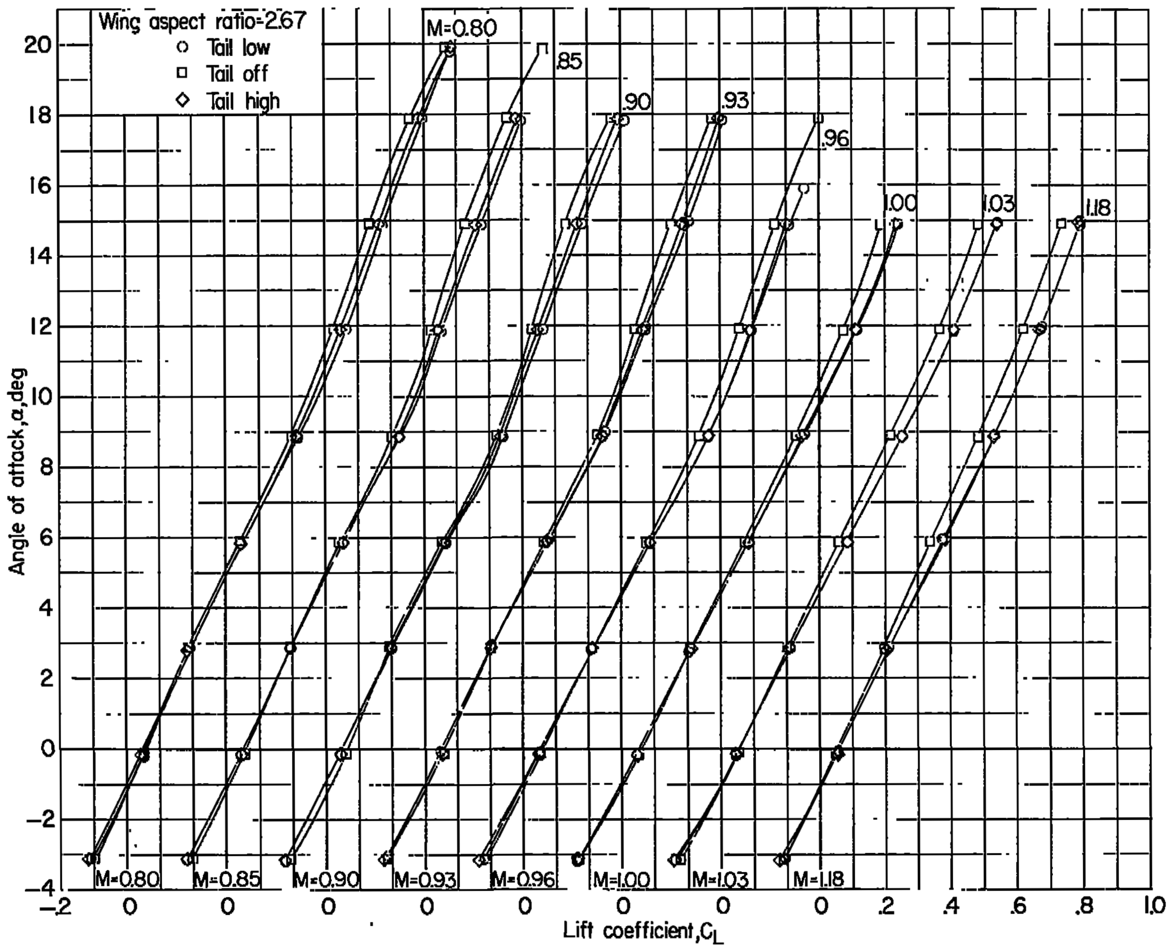
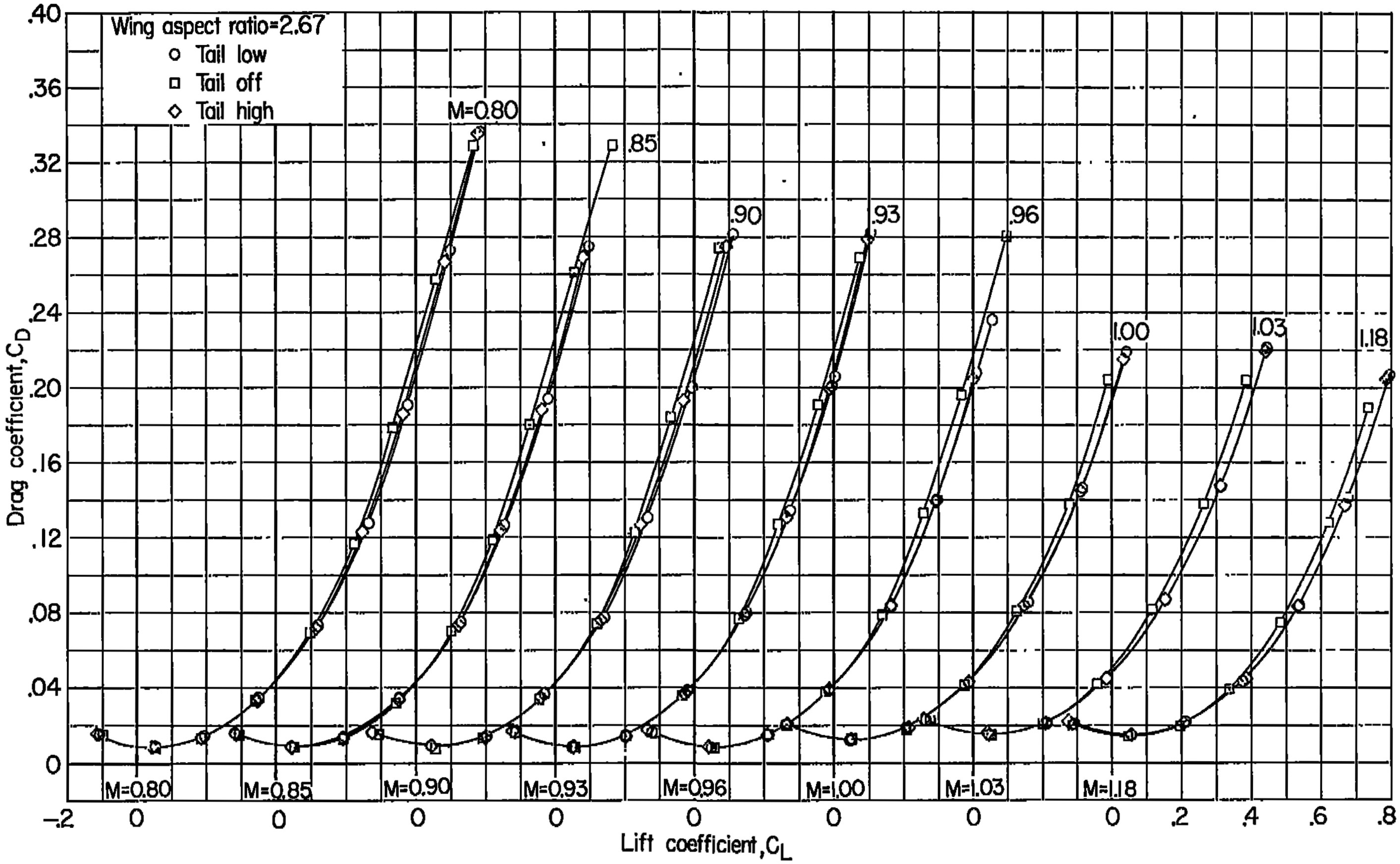


Figure 3.- Variation with Mach number of Reynolds number based on wing mean aerodynamic chord.



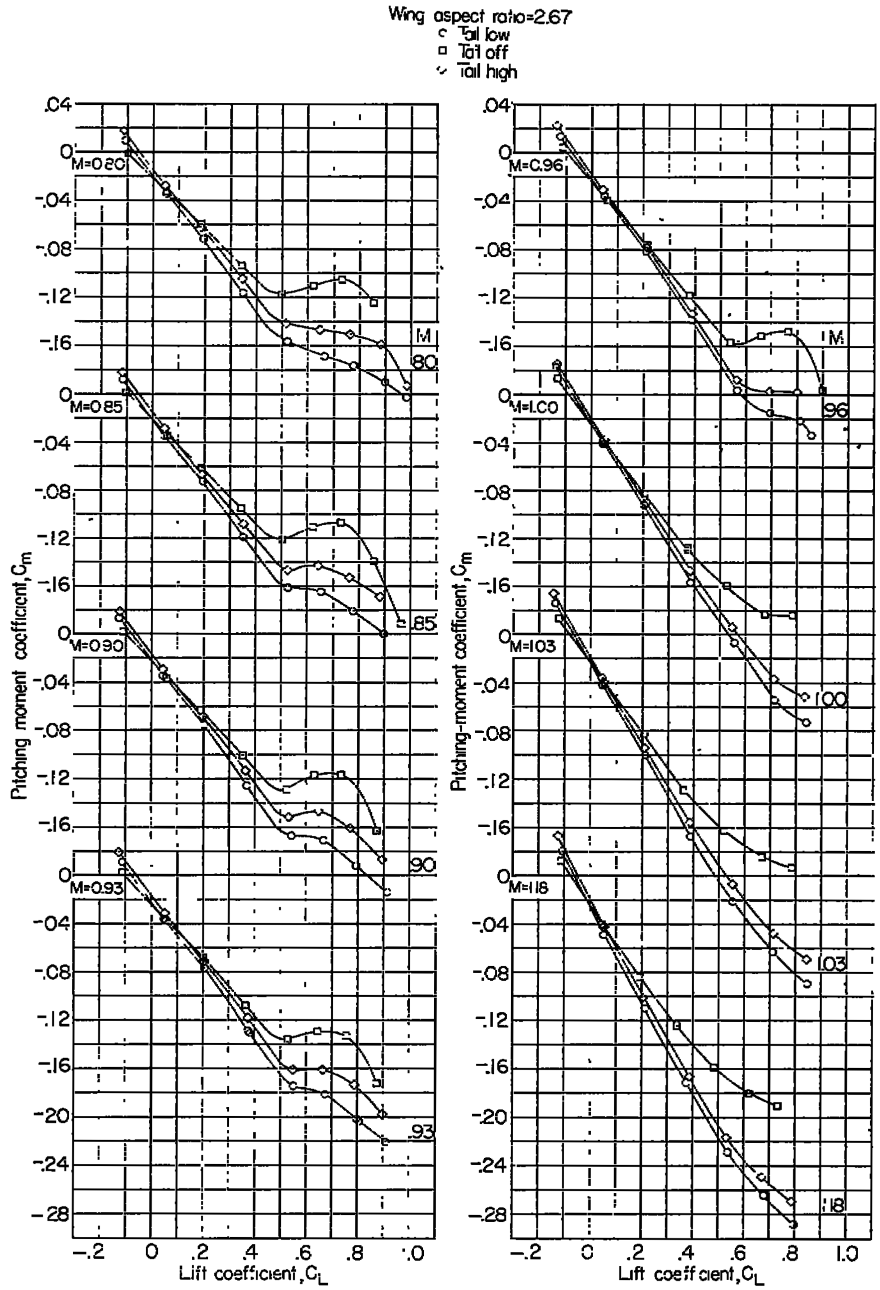
(a) Variation of α with C_L.

Figure 4.- Aerodynamic characteristics of the aspect-ratio-2.67 wing-body configuration with and without the horizontal tail.



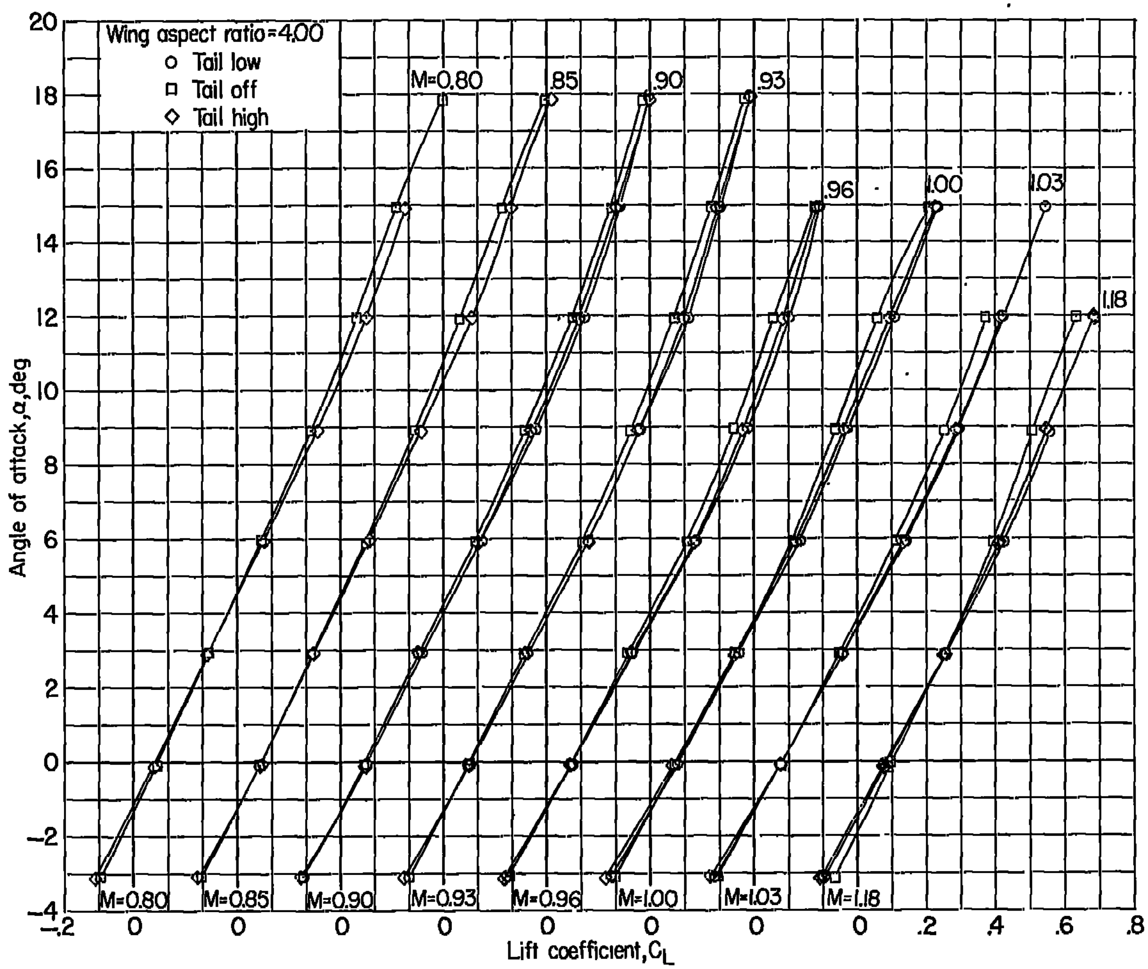
(b) Variation of C_D with C_L.

Figure 4.- Continued.



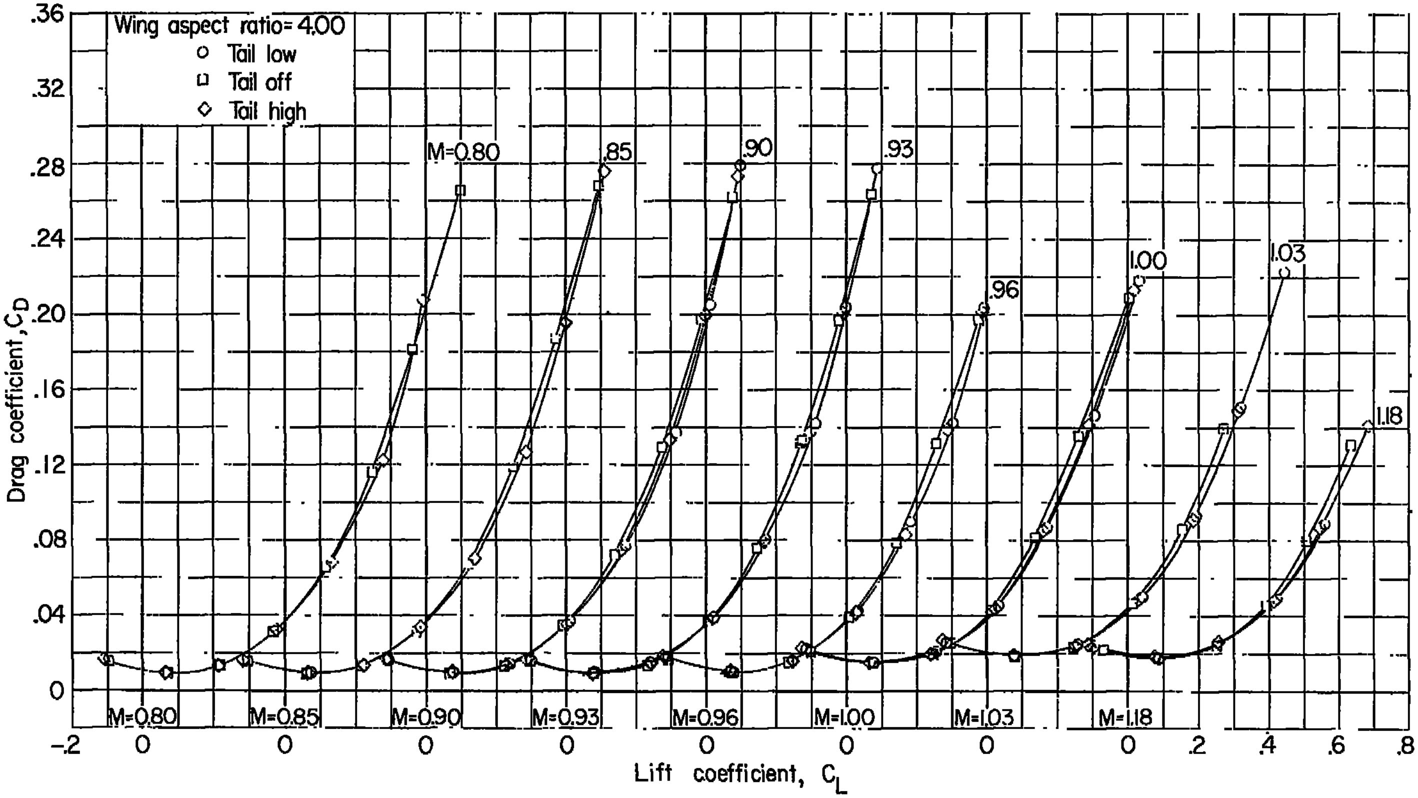
(c) Variation of C_m with C_L.

Figure 4.- Concluded.



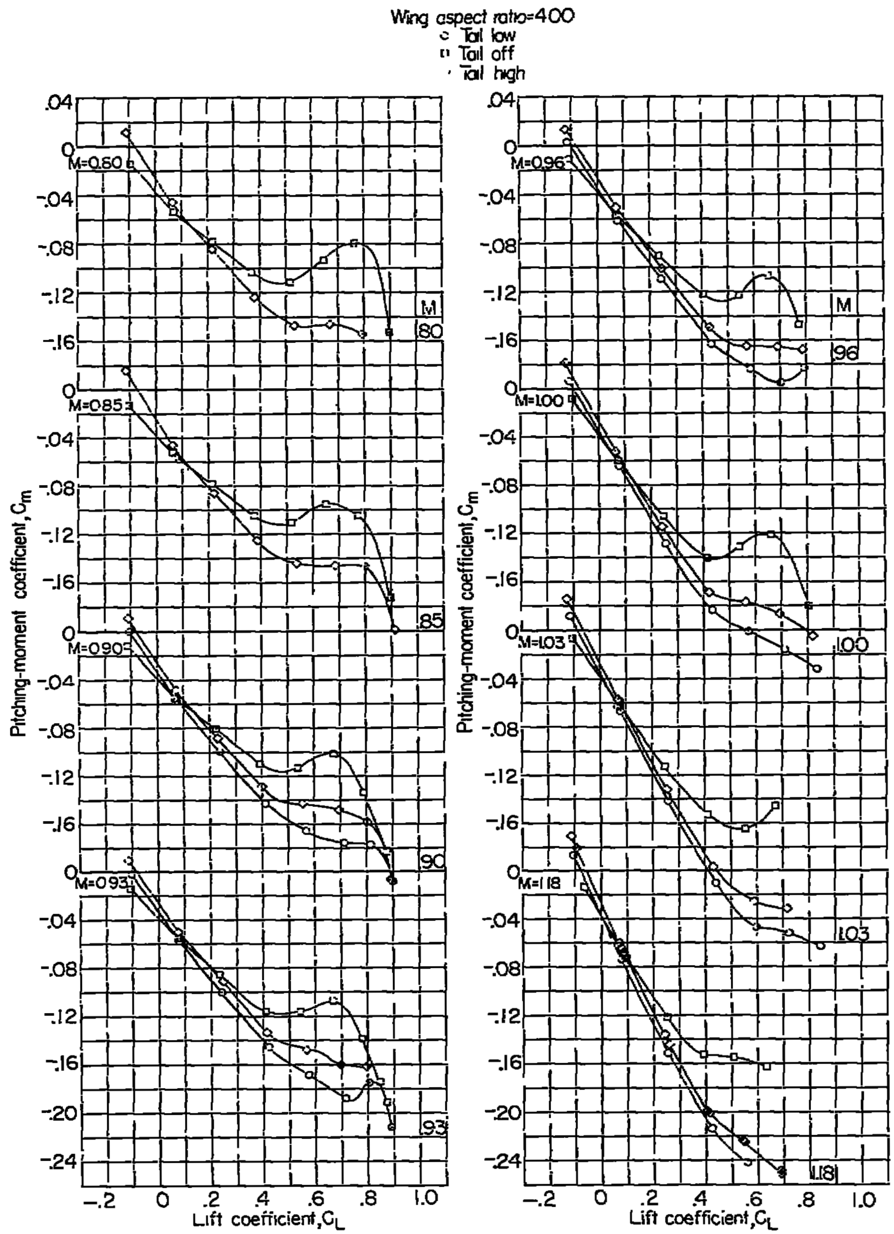
(a) Variation of α with C_L.

Figure 5.- Aerodynamic characteristics of the aspect-ratio-4.00 wing-body configuration with and without the horizontal tail.



(b) Variation of C_D with C_L.

Figure 5.- Continued.



(c) Variation of C_m with C_L.

Figure 5.- Concluded.

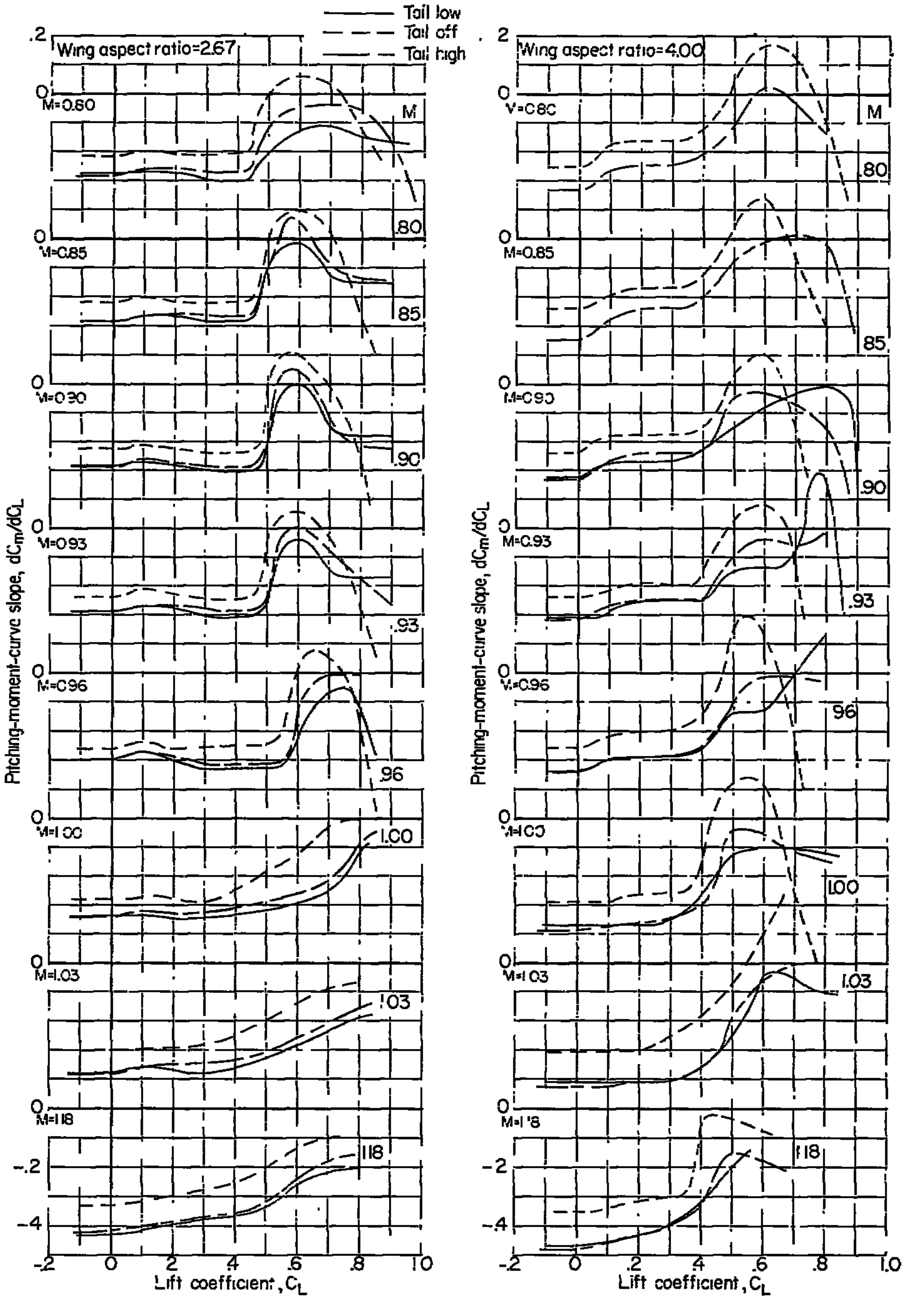


Figure 6.- Variation of dC_m/dC_L with lift coefficient for the wing-body and wing-body-tail configurations.

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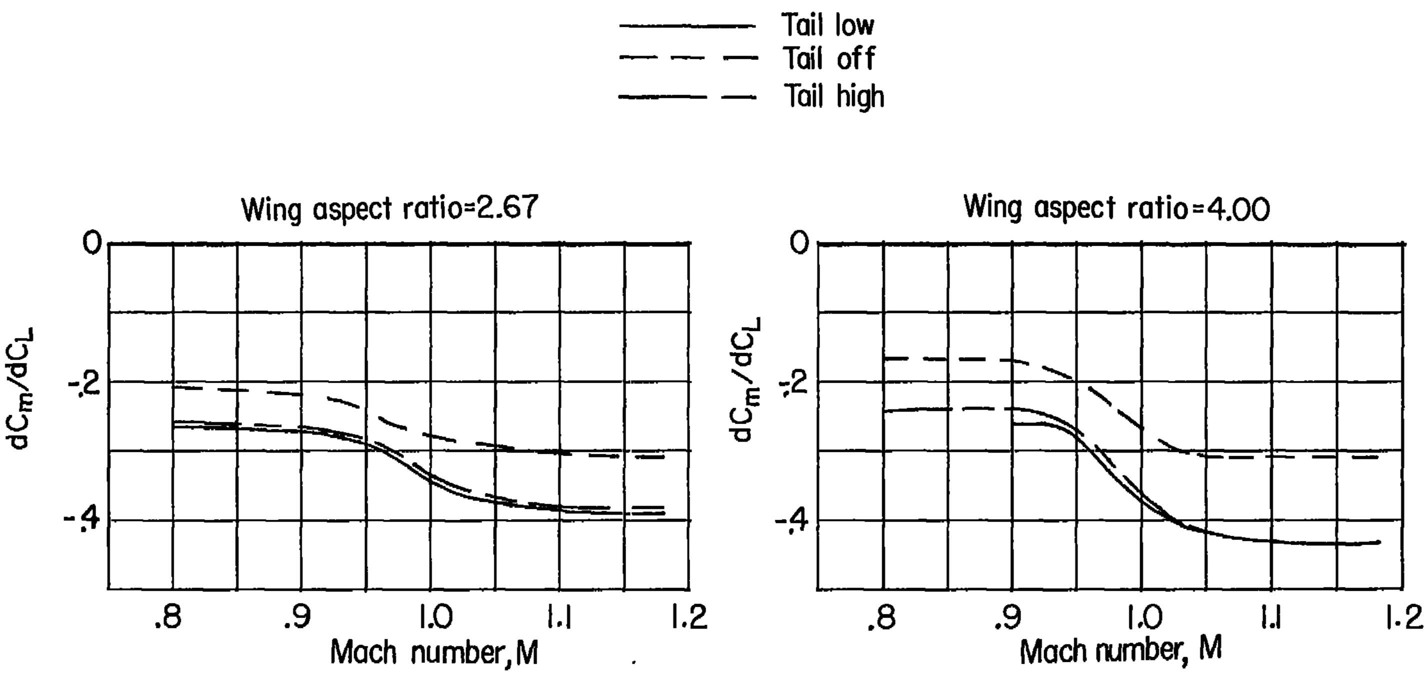

Figure 7.- Variation of dC_m/dC_L with Mach number for the wing-body and wing-body-tail configurations at a value of C_L of 0.2.

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